Identification of trends into dose calculations for astronauts through performing Sensitivity analysis on calculational models used by the Radiation Health Office

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Abstract

The Radiation Health Office (RHO) determines each astronaut's cancer risk by using models to associate the amount of radiation dose that astronauts receive from spaceflight missions. The baryon transport codes (BRYNTRN), high charge (Z) and energy transport codes (HZETRN), and computer risk models are used to determine the effective dose received by astronauts in Low Earth orbit (LEO). This code uses an approximation of the Boltzman transport formula. The purpose of the project is to run this code for various International Space Station (ISS) flight parameters in order to gain a better understanding of how this code responds to different scenarios. The project will determine how variations in one set of parameters such as, the point of the solar cycle and altitude can affect the radiation exposure of astronauts during ISS missions. This project will benefit NASA by improving mission dosimetry.

Introduction

The RHO has a computational model that uses the BRYNTRN and HZETRN transport codes and mission parameters in order to assess risk for astronauts during their International Space Station missions. The model calls for the input file that deals with the specifics of that mission such as the altitude that the mission was flown at, the value of the F10.7 radio flux, sunspot number, the solar modulation parameter (PHI), measured absorbed doses from the Radiation Area Monitors (RAMs), and the measured dose from the Crew Passive Dosimeters (CPDs). The CPD are worn at all times. The program also calls for another file that produces a table of doses imparted by different particles at various depths. The computational model uses these input files to calculate the risk assessment for an astronaut on an ISS mission. At the end of the program, the model normalizes the effective dose by multiplying it by the ratio of the CPD to the modeled skin dose of a RAM in a heavily shielded location which becomes the new effective dose. As I tested the effect of one parameter, the other inputs were held constant. Since, the effective dose is modified by the CPD and the RAM. These parameters were increased and decreased by 20% in order to see its effect on the calculation of the effective dose. The task is to test the sensitivity of various parameters on the calculation of the effective dose.

The F10.7 Radio flux is a measure of solar activity that is emitted at 10.7 cm wavelength. The dose can change depending on solar activity. Generally, the effective dose has an inverse relationship with solar activity. Therefore when solar activity is high, the effective dose is low. Figures 1a and 1b are graphs of effective dose as a function of the F10.7 Radio flux at 345 kilometers and 420 kilometers respectively. F10.7 was in a range from 70 x 10^{-22} Watts per square meter per hertz to 170 x 10^{-22} watts per square meter per hertz. This range is to cover from solar minimum conditions to solar maximum conditions; however, as the radio flux increases, its effect on the calculation is insignificant at low and high altitudes. The RAMs and CPD were increased and decreased by 20%. When the RAMs and CPD are increased by 20% the

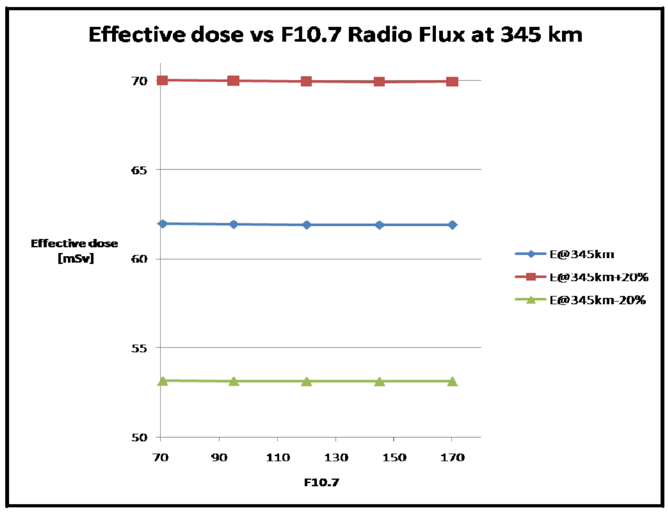

Figure 1a Effective dose vs. F10.7 Radio Flux at 345 km.

effective dose was higher, yet the effect due to F10.7 has an insignificant effect on the calculation of the effective dose. The same is true when the RAMs and CPD are decreased by 20%. In figure 1b, there were some outliers

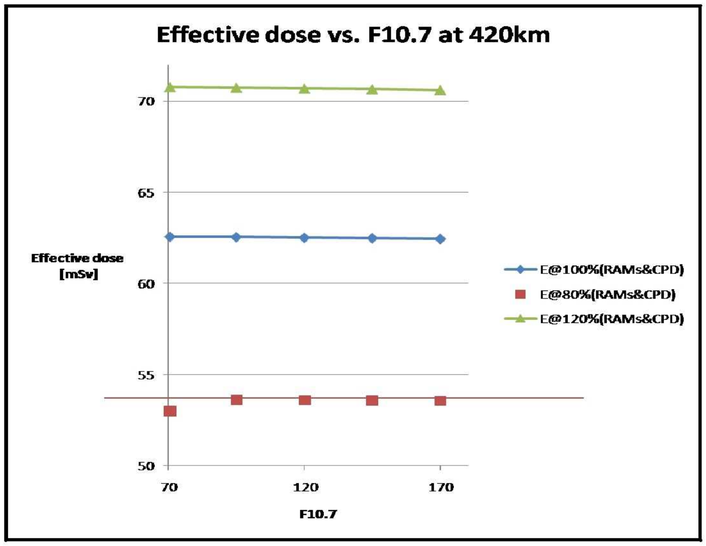

Figure 1b. Effective dose vs. F10.7 at 420 km

when the RAMs were artificially decreased by 20% which coincides with the drop in the normalization factor CTLD. In that instance the program was simply pushed too far.

Figure 2 is a graph of effective dose as a function of PHI with unmodified RAM and CPD values at different altitudes. PHI is another representation of solar activity. High PHI values correspond to high solar activity whereas low PHI values correspond with low solar activity. It shows that

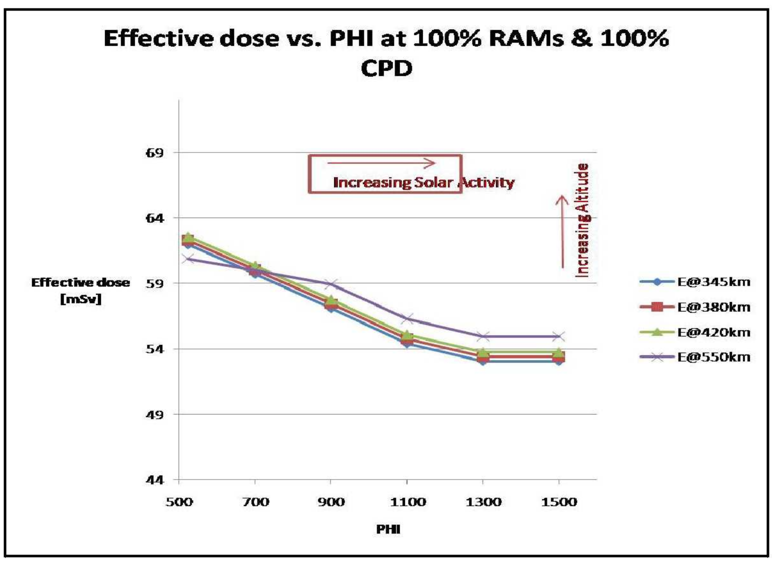

Figure 2. Effective dose vs. PHI

the effective dose decreases as the PHI value increases. The effective doses differ by a few percent which suggest that the impact of PHI on the calculation of the effective is slightly significant. Thus, the PHI has a slight effect on the calculation of the effective dose.

Figure 2 shows four curves representing 345, 380, 420, and 550 kilometers from bottom to top respectively. It is important to note that the trend with altitude shows that the effective dose increases with increasing altitude which is expected. Therefore, the model does respond to the changes in altitude accordingly. However, when the altitude was set to 550 kilometers, the first two effective doses on that curve were lower than expected. In those cases, the normalization factor, CTLD, was calculated to be too low at those PHI values which caused the drop in the effective dose. As PHI increases the calculation of CTLD must have changed to be within a reasonable range because the curve began to trend like the others. As I tested this parameter I found out that the model does not show a significant change once PHI is greater than 1300; thus, the calculation of effective dose leveled out at the end of the curves.

Among the parameters that are used in the calculation of the effective dose, phi, altitude, and the ratio are the major contributors. Although, phi and altitude do not seem to have a major effect on the calculation of effective dose, the changes are still significant, and they follow the expected trends. After all, the effective dose increases with altitude, and it decreases with phi. However, the ratio is the main driver in the effective dose. Thus, depending on how the CPDs compare to the space weather environment. The effective dose can be driven higher or lower. Also, it is important to note that the parameters may work in conjunction with other parameters. This would explain why the changes in F10.7 would not have a significant effect on the effective dose. Since, F10.7 and phi are a representation of solar activity, then changing these parameters separately may not be enough to produce the effects that are expected. Realistically, isolating a single parameter describes its effect; however, if the parameter is a similar type of others then by changing the group together should causes the changes that trend as expected.

Goals and Purpose

The Radiation Health Office is a part of the Space Medical Division at Johnson Space Center. The group wants to be sure that the risk model can give an accurate description of the space environment because of the safety issues. While astronauts are in space, they are exposed to radiation from the Sun, trapped particles in the geomagnetic field, and interstellar space that can affect their health. The National Council of Radiation Protection and Measurements Report No. 132 sets a standard 10 year career limit such that the astronaut will not exceed a three percent "excess cancer mortality" (1). This limit depends on the age and gender of the astronaut. Since, ISS mission are long duration, there is a need to know when an astronaut is no longer able to participate in another mission due to health risks. Therefore, the ability to project and assess risk is key to preserving the astronauts' safety.

Impact

My mentor provided me with a lot of opportunities to experience what it is like to work at NASA. She has taken me to staff meetings where I saw how the organization fits in with the rest of the directorate, and it has provided a lot of insight into the health aspect of space exploration. She has encouraged me to attend other meeting such as the Flight Readiness Review for STS-128 where even though the radiation health aspect of the meeting was very small in comparison of other issues such as water on the ISS. She has taught me that all roles are equally important.

During this internship, I was exposed to a completely different field of study. This project dealt with Health Physics, so I ended up gaining a lot of information on nuclear physics. I learned a lot about the effects that radiation can have on the body. Like, particles disrupting DNA, thus causing chromosomal aberrations or inducing cancer. This internship has cemented my interest in space physics and opened a possible career that I could specialize in.

References

[1]National Council on Radiation Protection and Measurements. "Radiation Protection Guidance for Activitiesin Low-Earth Orbit," NCRP Report No. 132. National Council on Radiation, 2000.